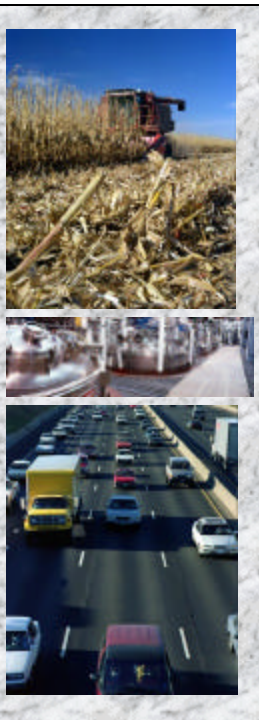


Bioethanol From Corn Stover: A Life Cycle Assessment

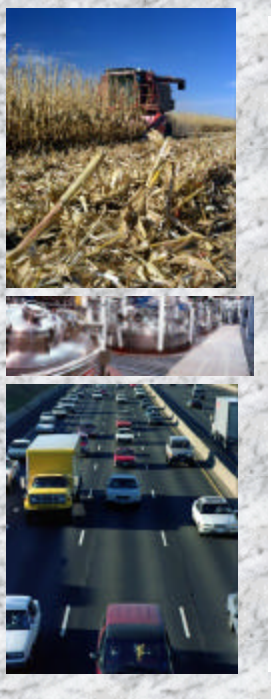
Cindy Riley

John Sheehan

Biotechnology Center for Fuels and Chemicals

National Renewable Energy Laboratory

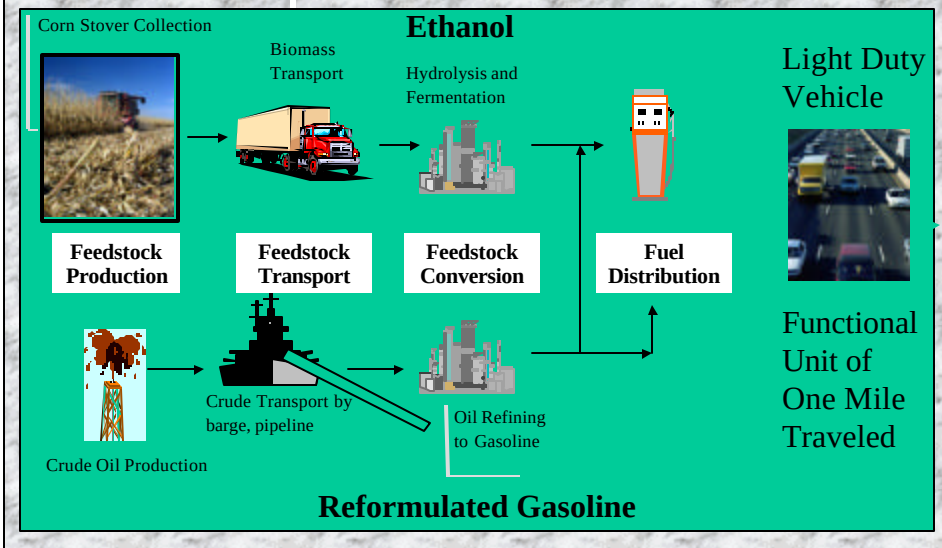
A U.S. Department of Energy National Laboratory

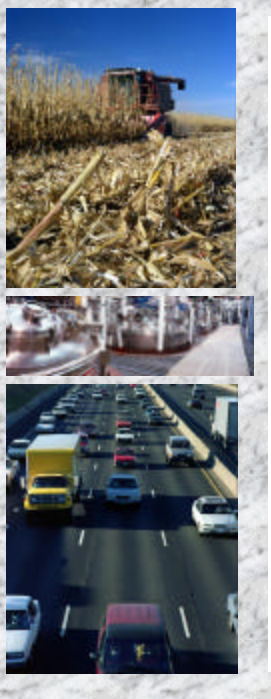


Life Cycle Analysis—What is it?

- A "comprehensive" accounting of a product's flows to and from the environment
  - Air, water and solid waste emissions
  - Energy resources
  - Other primary resources extracted from the environment
- "Cradle to grave"

System Boundary

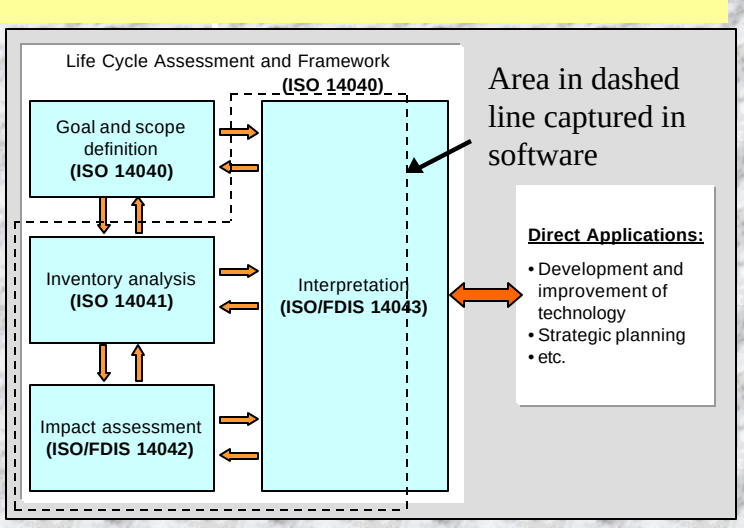




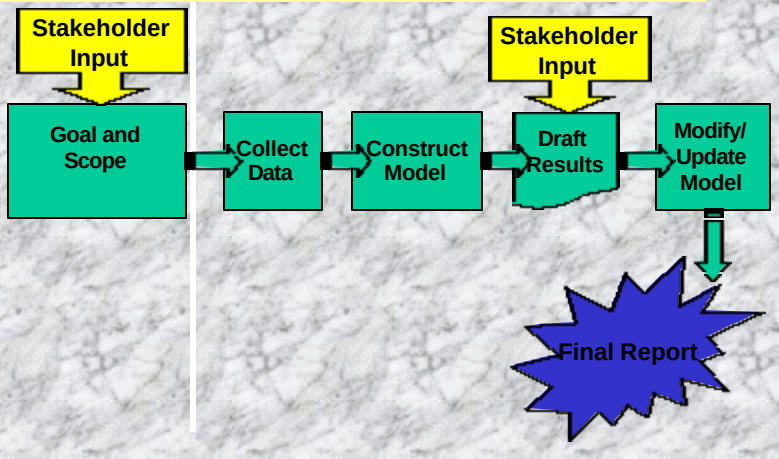
You know you've arrived when you have software...

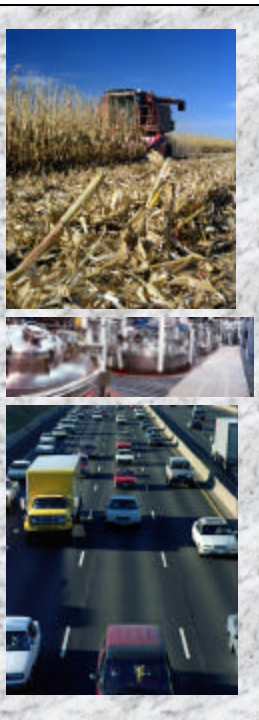
- NREL's 1st ethanol LCA—Lotus™ spreadsheet
- Evaluation of alternative energy technologies
  - Argonne National Laboratory life cycle spreadsheet model—GREET™
- Commercial tools
  - Ecobalance TEAM™ and DEAM™
  - A variety of other commercial products

You know you've arrived when you have standards...



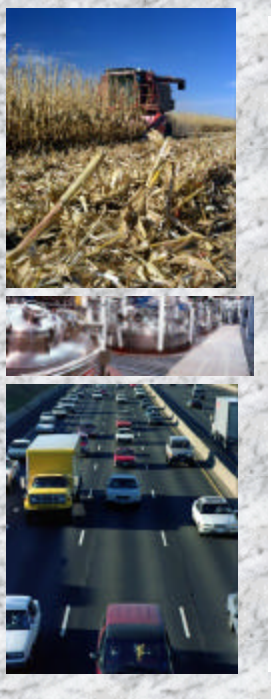
Life Cycle Analysis Overall Plan





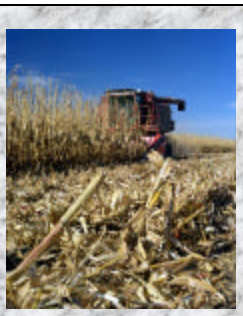
Key Stakeholders

- Environmental groups
- Farmers
- Automakers
- Ethanol producers
- USDA
- EPA
- DOE



Key Sources of Data

- Oak Ridge National Lab
  - Macroeconomic modeling
  - Collection and transport
- Colorado State University Natural Resources Ecology Laboratory
  - Modeling of soil carbon and soil nutrient cycles
- National Renewable Energy Lab
  - Conversion technology

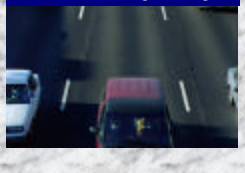


Defining the Goal

- "The intended application, the reasons for carrying out the study and the intended audience" (ISO 14040)
- Goal as defined by stakeholders
  - Intended application: bioethanol from corn stover to ethanol
  - Reasons for study: begin a dialogue on the sustainability of this technology
  - Audience: farmers, processors, regulators, policy makers, researchers and the public at large

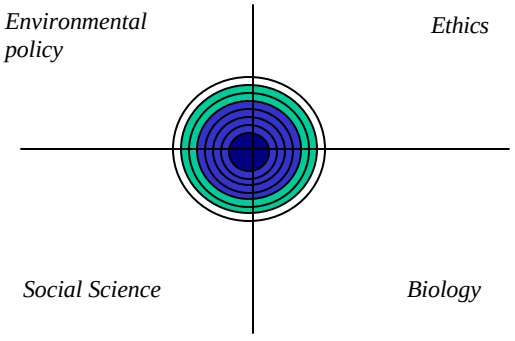
"As we cross the circles inward toward toward the point at which the quadrants meet, we find ourselves in an increasingly unstable and disorienting region. The ring closest to the intersection, where most real-world problems exist, is the one in which fundamental analysis is most needed."

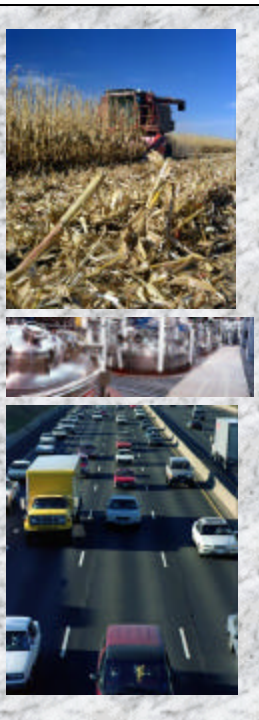
E.O. Wilson in *Consilience*(1998)



Sustainability: Buzzword or Buzzsaw

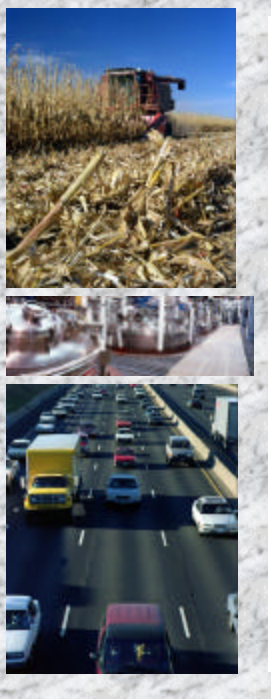
- Working at the intersection of science and philosophy





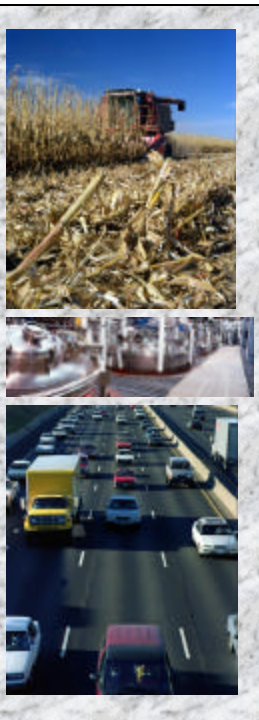
How Do We Measure Sustainability?

- Absolute measures of sustainability make little sense
- We agreed to approach the question on a relative or directional basis
  - Are we more or less sustainable?
  - Probably not a single measure
  - Qualitative, value-oriented



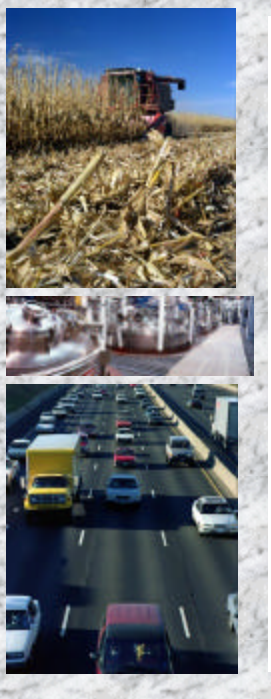
Sustainability Measures

- Fossil energy avoidance
- Land use and biodiversity
- Greenhouse gas
- Soil sustainability
  - Erosion, organic carbon, soil nutrients
- Urban air emissions
- Air and water toxics
- Solid waste
- Eutrophication
- Acidification
- Community—rural jobs, local economy



Setting the Scope

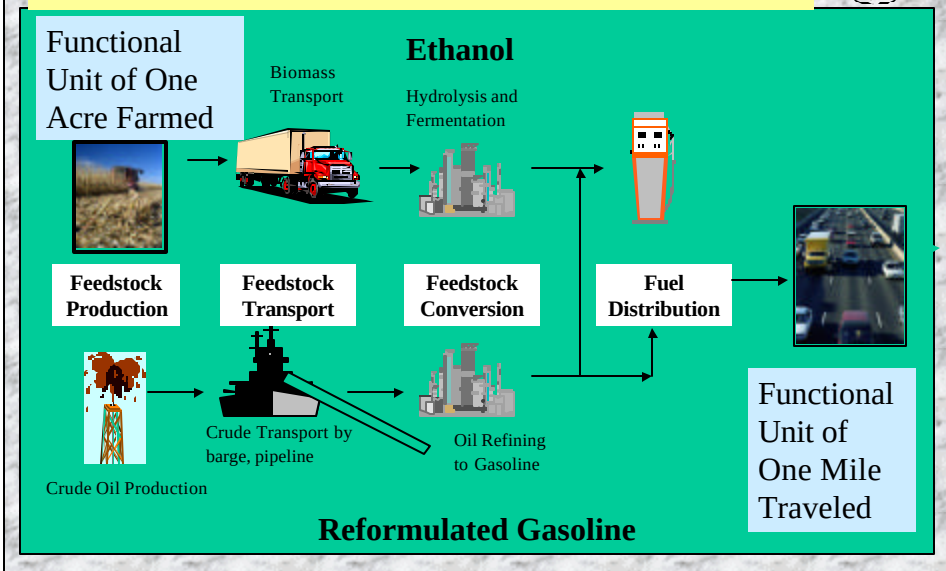
- Geographic:
  - State of Iowa
- Time
  - 2005-2010
    - E10, FFVs
    - 1st generation enzyme conversion
    - Conventional collection
  - Beyond 2020
    - Dedicated ethanol vehicle
    - Advanced enzyme technology
    - Novel collection options (whole plant, slurry transport)

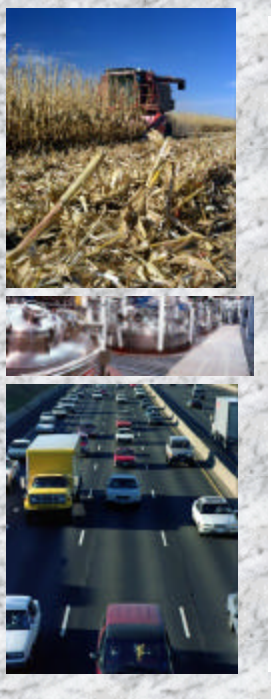


Setting the scope (cont'd)

- Functional unit—two radically different approaches
  - One mile driven in light duty vehicle
  - One acre of land farmed
- Two systems will be constructed to deal with each
- This dual approach comes from our agreement to focus on sustainability from two major perspectives

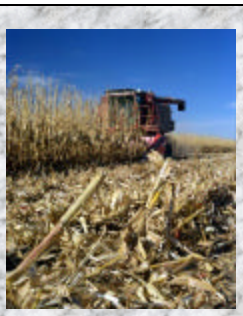
System With 2 Functional Units





Data Collection

- Soil impacts—GHGs, soil health
  - Probably the most critical part of the study
  - The Natural Resources Ecology Laboratory
    - Developers of USDA's Century model for soil carbon sequestration
    - These are real popular guys right now and we are excited to have them on board
- Stover collection and transportation
  - Relying on ORNL/cea studies
- Conversion
  - Revised corn stover process model results
- Fuel Use
  - Ford vehicle data for FFVs



Seeking Input

- Modeling and data collection are underway now
- Preliminary results will be available for review in December 2000
- Venues for input
  - Let us know if you want to participate in report review
  - Provide input via the web